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all the known forms of microbes, and shows that these microorganisms have different powers of receiving stains according to their ages.

If he be correct in the foregoing statements, many genera will be done away with. It is very interesting to follow his experiments showing the growth and development of one form into another, noting his methods of detecting the cells, etc., which methods show much labor and careful manipulation.

In treating of the typhoid germ he claims that it is not chromogenic. The work shows a marked difference in the various forms of the *Bacterium balbianii* (found in marine algæ), and the *Micrococcus prodigiosus* and the *Bacillus violaceus*, and follows them through the filamentous, dissociated, entangled, and zooglœic forms; it shows that they can live in air and may resist 100° C., that they assume an orange color on the surface of certain solid media, and that they undergo endogenous spore formation. It also shows that the *Bacterium osteophilium* is mostly found in macerated human bone surrounded with yellow fat, and that this also undergoes endogenous spore formation. He shows an evolution cycle, divided into the filamentous, dissociated, entangled, and zooglœic states. These different states correspond to a morphological grouping, and are due to the nutritive media, temperature, pressure, amount of oxygen, etc. Consequently, many morphological forms represent the same species. The zooglœic state merely represents a state of preservation. As has been said, the forms cannot determine the genera; and as we do not know at present the principal genera, we must not attempt to classify them.

It will be seen that Billet is working in the right direction to reduce bacteriology to an exact science.—S. G. DIXON.

Corals and Coral Islands. BY JAMES D. DANA.—About a half-century ago two exploring expeditions were almost simultaneously circumnavigating the globe; one under the command of Captain (afterwards Admiral) Fitzroy of the English Navy, the other under the command of Lieutenant (afterwards Admiral) Wilkes of the United States Navy. These two expeditions are chiefly memorable for the work of two brilliant young naturalists by whom respectively they were accompanied. In the English expedition went a recent graduate of Cambridge, Charles Darwin, whose dust now rests in Westminster Abbey near to that of Sir Isaac Newton, and whose discovery of natural selection—the law of gravitation of organic nature—makes his name an epoch-making one in science since that of Newton. In the American expedition went a recent graduate of Yale, who still lives, full of years and honors, his eye not dim and his natural force not abated, facile princeps of American geologists, James D. Dana. Among the results of those voyages, the most important (excepting, perhaps, the influence of the experiences of travel upon the growing minds of the great naturalists themselves) was the theory of the origin of barrier reefs and atolls, independently developed by Darwin in the study of the coral formations of the Indian Ocean, and by Dana in the study of those of the Pacific.

The problem of barrier reefs and atolls may be briefly stated. The reef-forming corals grow only in shallow water, seldom, if ever, reaching a depth of much more than one hundred feet. Their skeletons are broken by the waves, and their comminuted fragments consolidated into the reef rock. A belt of reef is thus naturally formed immediately adjoining the shore of a continent or island, or separated from the shore by a shallow channel, having a width of a mile, more or less. Such a channel is very apt to exist, since the water immediately in contact with the shore is apt to be too impure for the luxuriant growth of corals, while the conditions are most favorable for such growth on the outer margin of the reef. Such a reef is called a fringing reef, and its formation presents no perplexing problems. But the case is very different with the barrier reefs, which are separated from the shore of the continents which they border, or of the islands which they surround, by a deep channel, ten, twenty, one hundred, or more miles in width; and with the atolls, which are more or less irregular rings of reef rock, entire or broken by channels, standing out in mid-ocean away from any land, and enclosing lagoons, which are sometimes small and shallow, but which sometimes have a diameter of scores of miles and a depth much exceeding the limit of coral growth. On the outside of both barrier reefs and atolls the bottom generally slopes off pretty rapidly into truly oceanic depths.

The solution of the problem was given by Darwin and Dana in a theory which may be expressed in one word,—subsidence. Darwin had the priority in the formulation and publication of his views, and the theory is most commonly called by his name; but Dana's work was equally independent, and he was able to illustrate the theory with a much more extensive series of observations than Darwin had the opportunity to make. It seems, therefore, most just to link together the two illustrious names, and to call the theory the Darwin-Dana theory. Let the earth's crust in a region of coral reefs undergo a subsidence not more rapid than the rate of coral growth, and fringing reefs will obviously be converted into barrier reefs. Since the corals always grow most rapidly at the outer margin of the reef grounds, the inevitable effect of subsidence will be the widening and deepening of the channel between the reef and the shore; and this is exactly what is required to transform a fringing into a barrier reef. If the reef was formed around an island, continued subsidence will suffice to convert the barrier reef into an atoll, the original island disappearing beneath the waters of the lagoon. Since the outer wall of the reef, though somewhat steep, is never precipitous, subsidence still continued after the formation of an atoll must diminish the size of the atoll and tend to obliterate the lagoon. The last stage of a coral island disappearing by continued subsidence is therefore a mere dot of coral rock.

The theory, in its charming simplicity, reminds one of Columbus's egg. It accounts for the facts with a marvellous perfection. And the correlation which it traces between the formation of those

> "Summer isles of Eden lying in dark purple spheres of sea,"

and the vast crustal movements involved in continental changes of level in late Tertiary and Quaternary times, opens one of those glimpses of the unity of nature which give to scientific speculation a poetic sublimity. The Darwin-Dana theory was immediately and well-nigh universally accepted. Probably the first thought of almost every geologist, when the theory was announced, was, "Why did I not think of that myself?"

The subsidence theory, however, has had a rather curious history. After an undisputed reign of a third of a century, its title to the throne has been recently questioned, and, in the judgment of some of the ablest geologists, its days are numbered. The Duke of Argyll, who often (as King James said of Lord Bacon) "writes of learning like a Lord Chancellor," has made the assumption of the certain falsity of the subsidence theory the basis of a wholesale charge against the morality of scientific men, alleging that the majority of geologists have formed a "conspiracy of silence" to suppress the new views, in order to maintain before the public the infallibility of the idolized Darwin. It is, then, with a special interest that we turn, in this new edition of Dana's classical work, to the pages in which he deals with the recent discussion of the subject, and, after the mature deliberation of a half-century, defends the theory whose discovery was one of the earliest of his great achievements.

It is undoubtedly true that both barrier reefs and atolls may be formed without subsidence. If the water off the shore of a continent or island deepens very gradually, the water near the shore line may be too impure for coral growth, and the favorable conditions for such growth may be only attained at a distance of several miles from land.

In such situations the primary condition of the reefs would be that of barrier reefs (though differing from most barrier reefs in not sloping off rapidly into very deep water). The reefs of Florida are probably examples of this sort. Moreover, it was long since recognized by Chamisso, that, if the summit of a submarine volcano (or a shoal of any origin whatever) should be within the hundred-foot limit, the coral formations thereon would naturally assume the atoll form—a ring of reef encircling a lagoon—as the result simply of the more luxuriant growth of the corals on the outside than in the middle of the reef grounds. Murray, in his theory of atolls, in addition to the more luxuriant growth of corals on the outside, calls in the solvent action of the sea-water in the middle of the reef grounds in explanation of the lagoon,—an action whose importance he seems greatly to overrate.

A strong objection to Chamisso's theory of the origin of atolls has been found in the amount of coincidence which it requires. All atolls must represent submarine volcanoes (since no other shoals are likely to occur in mid-ocean), rising to within a hundred feet of the sea-level. The occurrence of so many independent volcanoes attaining so nearly the same altitude appears improbable. Murray meets this argument with the suggestion that forces are in action which tend to reduce all oceanic volcanoes to a uniform altitude, since rain, streams, and ocean waves tend to degrade to sea-level all peaks that rise above that level, while deposits of skeletons of pelagic life tend to raise the level of shoals which are yet too deep for coral growth. An island of any height could of course be leveled in time by the combined effects of subærial and marine denudation; and, as it is not unlikely that volcanic islands may have been formed in various geological periods, it is conceivable that scores or even hundreds of oceanic volcanoes, originally of various heights, might all exist to-day in the condition of shoals. But it is certain that wave-action could never degrade an island much below the water-level. The formation of atolls with deep lagoons, on the basis of volcanic cones truncated by wave-action, would seem impossible without subsidence. The depth of the lagoons, which is generally considerable in the larger atolls, and which sometimes amounts to more than three times the extreme depth of coral growth, seems, in fact, a conclusive argument for the subsidence theory. In commenting on the theory of Murray, which proposes to account for the foundation ot coral islands by the accumulation of the remains of pelagic life, and to account for deep lagoons by the solvent action of the water, Darwin is reported to have said to a friend, not long before his death, that he could not understand how the water could possess so great solvent power in the lagoon of an atoll, and so little solvent power anywhere else. We find ourselves in very much the same state of mind.

The distribution of coral formations in the Pacific accords exceedingly well with the Darwin-Dana theory. South and west of the Sandwich Islands there lies a large area nearly or quite destitute of islands of any kind. Passing southward and westward from this area —the area of maximum subsidence, according to the theory—we traverse zones characterized respectively (though with much local irregularity, as might be expected) by the predominance of small atolls and lagoonless islands, of large atolls with broad and deep lagoons, and of high islands encircled by barrier reefs, reaching at last an apparent limit to that area of subsidence in the fringing reefs of New Hebrides and the Solomon Islands.

Dana has pointed out a very interesting evidence of subsidence in the dissected form of the coast-line of the high islands encircled by barrier reefs,—narrow ridges radiating outward in "spider-leg" fashion between deep bays. A deeply-dissected coast-line, on continent or island, is rightly regarded as evidence of subsidence, since valley-making is the characteristic work of rivers or glaciers.

The limits of this article allow only a mention of the blocks of limestone on the submarine slope of Tahiti far below the reach of wave-action, and the discovery of coral rock hundreds of feet below the sea-level in the artesian borings at Honolulu, rightly regarded by Dana as evidences of subsidence.

We are inclined to find a confirmation of the Darwin-Dana theory in a consideration which many will regard as too speculative to have any weight. Although there are some exceptions, Darwin's generalization appears, on the whole, to be well established, that areas of barrier reefs and atolls are destitute of active volcanoes, while active volcanoes are found in areas of fringing reefs. If we adopt the view that the interior of the earth, though solid, is mostly in a state which might be called potential liquidity, the relations of temperature and pressure everywhere, beneath a thin, cold crust, being such that the slightest local diminution of pressure will allow extensive liquefaction,—a theory which seems perhaps most satisfactorily to harmonize the apparently conflicting indications of geological and physical evidence bearing on the subject,—it seems probable that the fire-lakes from which volcanoes are fed may be developed generally in areas of local elevation and consequent local diminution of pressure. If, then, the presence of barriers and atolls may be accepted as a mark of regions undergoing subsidence, in distinction from regions stationary or undergoing elevation, Darwin's generalization would be seen to be not a mere coincidence, but a dynamical law.

We believe, in view of all the evidence brought forward in recent discussion, that it is altogether probable that extensive subsidences of the ocean's bed have taken place in Tertiary and Quaternary times, and that the majority of barriers and atolls are the result of such subsidence, though conceding that both barriers and atolls may be formed without subsidence.

We have devoted most of this review to the examination of the theory of barriers and atolls, in view of the interest which recent discussion has aroused. The book before us is, however, by no means a controversial work, nor is it chiefly occupied with the presentation of the Darwin-Dana theory. On the contrary, in a remarkably many-sided way, Professor Dana has given us all phases of the subject: the structure, physiology, and taxonomy of the coral animals; the mode of formation of reefs and islands; the far-reaching geological inferences which the facts suggest; the fantastic beauty of those gem-like islands; and, in sad contrast, the lack of the essential conditions of an indigenous or self-supporting civilization,—

> " Where every prospect pleases,
> And only man is vile."

The professional geologist will turn to the book for the latest and most matured views of one preëminently entitled to speak with authority. The student will find in it a well-digested encyclopedic work of reference. The general reader will follow with delight the steps of one who, with a love of nature so pure and childlike,

> " —— Wandered where the dreamy palm
> Murmured above the sleeping wave;
> And through the water clear and calm
> Looked down into the coral cave."

In regard to the externals of the book, it is enough to say that the publishers have got it up in a style worthy of the contents. The book is richly illustrated. In this edition several new maps are added, and a few beautiful colored plates of corals and sea-anemones.—WM. NORTH RICE, in *New Publications.*